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ON-SITE CONSTRUCTION PRODUCTIVITY IMPROVEMENT
THROUGH
TOTAL QUALITY MANAGEMENT

BY

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REPORT

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ON-SITE CONSTRUCTION PRODUCTIVITY IMPROVEMENT THROUGH

TOTAL QUALITY MANAGEMENT

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1.1. TOTAL QUALITY MANAGEMENT PHILOSOPHIES

1.1.1. NEED FOR IMPROVEMENT

The construction industry is experiencing increasing competition, rising legal cost related to cost overruns and schedule delays, and decreasing profit margins. These symptoms are forcing many construction companies to realize that fundamental changes in the way they conduct business must be made if they are to remain competitive. Consequently, many construction companies are beginning to adopt the methods and ideas of Total Quality Management (TQM) used by many manufacturing companies to improve the state of their industry[1]. TQM management techniques have been successful in manufacturing, service, and most recently in construction industries. Three Japanese contractors have earned the coveted Deming Prize for quality improvement since the mid-1970s[2]. This progress was made despite the fact that construction projects are a unique one time process.

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[1]"Quality Management Organizations and techniques", Consturction Industry Institute, Source Document 51, (Aug 1989), p. 54.
[2]Ibid., p. 7.

1.1.2. TQM FUNDAMENTALS

TQM is a complete management philosophy with the fundamental objective of achieving customer satisfaction through continuous improvement of performance at all levels. TQM management philosophies promote teamwork, continuous process improvement, customer and supplier involvement, innovation, training, and education to achieve customer satisfaction, cost effectiveness, and defect free work. Continuous improvement of any company's performance measured in the basic terms of quality, cost, and schedule will eventually lead to customer satisfaction. Customer satisfaction will lead to a competitive edge.

The Japanese were the first to use modern TQM ideas in the early 1950s to transform their war torn nation into a global economic power. These concepts were developed from the teachings of Dr. W. Edwards Deming and Dr. Joseph M. Juran. The integration of a bedrock philosophy of management and statistical methods is the basis of the Deming management method[3]. Both Deming and Juran emphasize that the systems and processes, through which work is done, cause 85% of the problems encountered

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[3]Mary Walton, The Deming Management Method, (New York: The Putnam Publishing Group, 1986), p. 33.

in any organization, and that statistics can be used to control these systems. The company's workers are responsible for the remaining 15% of the problems (called the 85/15 rule). For example, a construction worker cannot perform a quality job when given faulty plans, poor instructions, or shoddy materials. Since upper management controls the systems for the performance of work, improvements can only be made when management embraces the obligation to improve the system not the workers. Management must encourage teamwork at all levels to identify and remove system problems; thereby, improve quality, decrease cost, and improve the productivity of each process. Deming illustrates the benefits of TQM through the chain reaction[4] shown in Figure 1-1.

Improve quality	➡	Cost decrease because of less rework, fewer mistakes, fewer delays, and better use of machine time and materials	➡	Improve productivity	➡	
➡	Increase market	➡	Stay in business	➡	Provide jobs and more jobs	

Figure 1-1 The Deming Chain Reaction

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[4]W. Edwards Deming, Out of the Crisis (Massachusetts Institute of Technology Center for Advanced Engineering Study, Cambridge, Mass, 1986), p.3

In 1979, Philip B. Crosby joined Deming and Juran in promoting quality consciousness through the publication of "Quality is Free." He provides a fourteen step quality improvement plan that begins with gaining an appreciation for what *quality* means, and for what the true "*cost of quality*" is in terms dollars. He contends that quality is conformance to requirements (not goodness), and that the only cost associated with quality is the cost of doing things wrong. Undoubtedly, it is always cheaper to meet the requirements right the first time[5]. The cost of quality is the cost associated with quality management activities (prevention & appraisal) plus the cost associated with failure. He uses the cost of quality to convince top management of the need for quality, and to provide a basis to track the progress of quality improvements[6].

Although TQM approaches differ, they all entail a cultural change where attention is focused on meeting the customer's requirements through continuous improvements in performance. The cost of implementing quality activities in the construction process is not cheap. However, as the quality of the construction process

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[5]Philip B. Crosby, Quality is Free, (New York: Mentor, 1979), p. 16.
[6]Ibid., p. 104.

(scoping, design, procurement, construction and start-up) improves, the cost associated with failures decreases (fewer change orders and delays, less rework and shorter schedule). The goal is to minimize the "cost of quality" (cost of failures), and maximize the return on investment[7] (cost of prevention and appraisal). Since TQM approaches are geared toward the manufacturing industries, construction companies must modify these approaches to compensate for the difference between the two industries[8]. The TQM method chosen must be well thought out and tailored to meet the specific needs of the organization, and must contain the following fundamental TQM elements:

1. Top Management Commitment and Leadership
2. Training and Education
3. Teamwork
4. Customer and Supplier Interaction
5. Process Measurement and Analysis
6. Continuous Improvement

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[7]"Cost of Quality Deviations in Design and Construction", Consturction Industry Institute, Publication 10-1, (Jan 1989), p. 23.

[8]CII, Soucre Document 51, p. 29.

1.1.3. TOP MANAGEMENT COMMITMENT AND LEADERSHIP

Quality improvements can begin only after top management admits that problems exist, and that improvements are necessary. Since top management controls the decisions and funds that define the systems causing 85% of the problems (85/15 rule), management must acknowledge that they need and want to improve. This admission creates a corporate environment where problems can be identified, analyzed and corrected through an integrated team effort.

Top management must provide leadership and direction by: (1) adopting a new philosophy about quality, (2) developing a method for measuring quality performance, and (3) implementing a well thought out TQM plan for achieving improvements. Crosby suggests that companies should define where management stands on quality through a company policy statement[9]. Likewise, Deming calls this commitment to quality "constancy of purpose."[10] Management needs to demonstrate a genuine concern for the people of its organization in order to gain their support, commitment and participation in these new methods. A prerequisite to gaining the commitment of

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[9]Crosby, p. 149.
[10]Deming, p.24

people is the elimination of adverse relationships and fear tactics so typical in today's construction environment. Deming states that, for better quality and productivity, people need to feel "secure." He notes that "secure" means to be "without fear."[11] A construction environment where workers are without fear of bringing up problems, asking questions, and expressing ideas is ripe for improvement.

1.1.4. TRAINING

Under TQM, everyone is responsible for improving quality. Consequently, appropriate training at all levels is essential to the success of a TQM plan. Basic instruction should include the fundamentals of the company's TQM approach, team problem solving, interpersonal communications and interaction, and rudimentary statistical methods. The training effort should be planned and tailored to fit each level in an organization, and its effectiveness should be measured and carefully tracked. Training must be a company priority, if continuous improvements are to be made. Training and education plans also should consider that quality improvements may mean fewer people, and that it is necessary to train these people to fill other

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[11]Deming, p. 59.

function. Deming emphasizes that management must make it clear that no one will lose their job because of improvements in productivity[12]. Education and retraining is an investment in people that will have long term benefits for the company, industry, and individual. Masaaki Imai, a noted Japanese quality expert said that "quality starts with training and ends with training."[13]

1.1.5. TEAMWORK

TQM activities involve everyone in the company, managers and workers alike. Teamwork is necessary to tap the vast resource potential of the labor force, and to develop cross functional cooperation that breaks barriers both horizontally and vertically within an organization. As teamwork spreads from one department to the next, interrelations, communications, and understanding strengthens the organization at all levels. When all the people of an organization become focused on a common goal, a cooperative climate develops where problems and causes are identified through teamwork.

The company's quality team organization is the structure for teamwork. Quality teams provide the

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[12]Walton, p. 84.

[13]Masaaki Imai, KAIZEN The Key to Japan's Competitive Success, (New York: Random House Business Division, 1986), p. 58.

organizational structure necessary to implement the TQM continuous improvement process. Chapter Two will expound on procedures for team problem solving techniques.

1.1.6. CUSTOMER AND SUPPLIER INTERACTION

If we are to achieve customer satisfaction, we must both understand what the customer needs, and be receptive to feedback about how well we have performed. Implementing feedback improvement ideas decreases the gap between the customer's needs and present process performance. Similarly, we should ensure that we express our needs and feedback to our suppliers. Every organization, department and individual involved in any process will play the roles of customer, processor, and supplier. Juran calls this phenomenon the triple role concept[14]. Figure 1-2 demonstrates the triple roles played by parties of the construction process.

In Figure 1-2, the Owner is the ultimate project customer. However, when he communicates his requirements, decisions and feedback, and provides funding he becomes a supplier to both the A/E Firm and the Constructor. Upon receipt of the Owner's requirements (input) the A/E switches roles from a

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[14]Joeseph M. Juran, Juran on Plannning for Quality, (New York: The Free Press, 1988), p. 17.

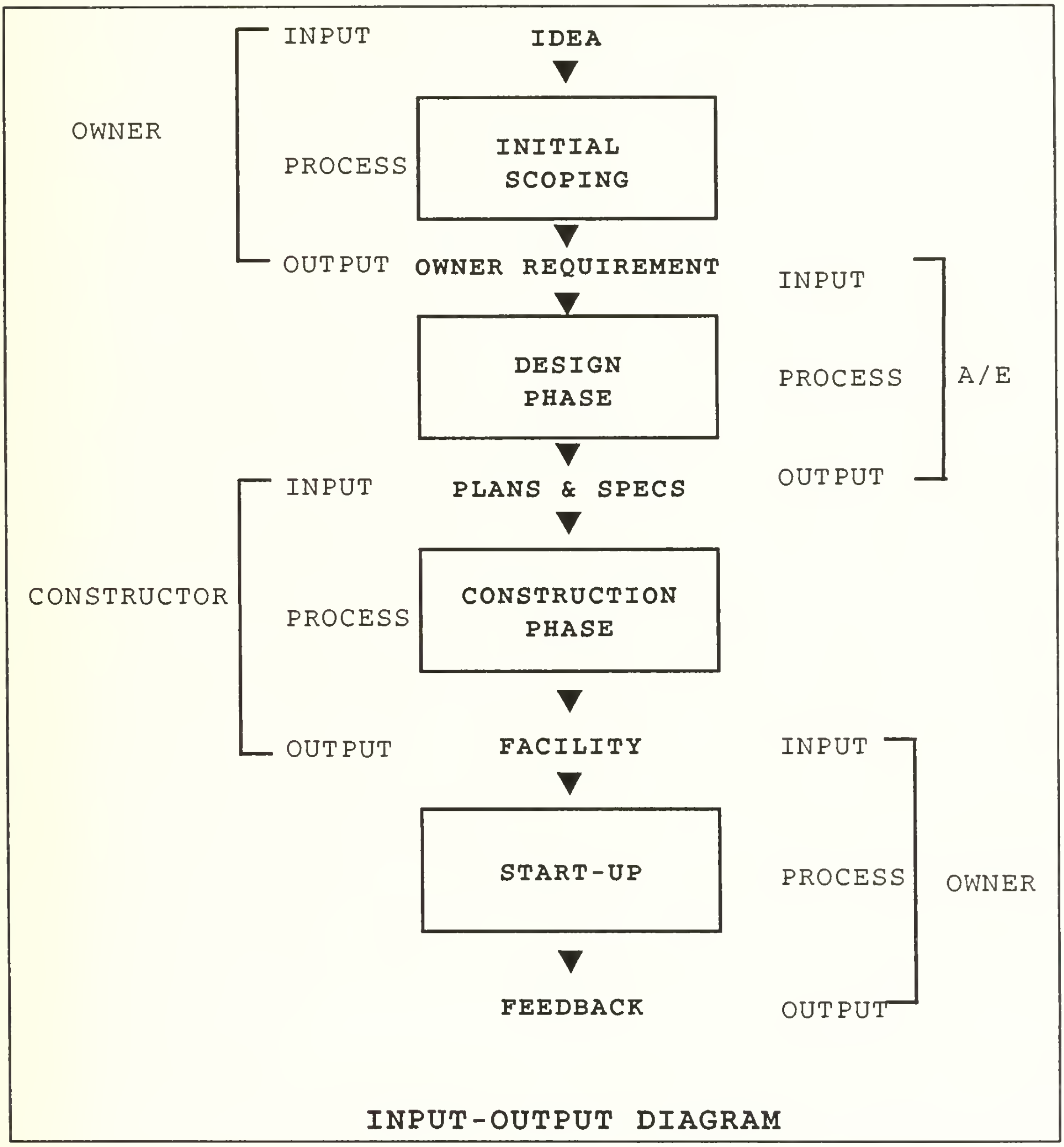

Figure 1-2 Juran's Triple Role Concept Applied to Construction Process

customer to a processor, and processes the plans and specifications (output). The Constructor, can then transform the input (plans and specifications) into a complete facility (output) that meets the Owner's (customer) requirements.

In each process, one must be aware of the needs of both external customers, and internal customers. External customers are external to the company; whereas, internal customers are within the company. Everyone invovled in the process needs to understand their customer's requirements, and know how their work affects others, and how others affect their work. The performance of the "suppliers" involved in the construction process, including owners, designers, constructors, vendors and labor force, depends not only on their own skills and desires to work, but also on how well they understand their internal and external customer's needs.

A recent Construction Industry Institute study determined that the cost of quality *deviations* on nine industrial projects averaged twelve percent of installed project cost[15]. Deviations occur when the work product

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[15]"Measuring the Costs of Quality in Design and Construction", Construction Industry Institute, Publication 10-2, (May 1989) p. 1.

fails to meet the requirements. Owners, designers, constructors, vendors and labor force should realize that they share a mutual win-win incentive for joining efforts and commitment to reduce the cost of project deviations. As demonstrated in the Deming Chain Reaction, commitment to quality improvement in construction will lead to decreases in construction cost, increases in productivity and profit margins, benefits to humankind in terms of better facilities, and more jobs through investment of savings toward future projects. In short, everybody wins.

1.1.7. PROCESS MEASUREMENT AND ANALYSIS

Before we can improve the quality of any process, we must have a method of measuring current performance. A *process* is the series of actions, methods and procedures directed to the achievement of a goal. Measurement of process performance will enable us to base decisions about the process on solid data rather than hunches. The system of measurement should consist of a *unit of measurement* and a *sensor*[16].

The unit of measurement is a defined amount of some quality feature that both expresses the customers needs, and permits evaluation of the process. The sensor

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[16]Juran, p. 70.

provides the method for collecting the data in terms of the unit of measure. Quality features are measured to provide a basis for improvement, not to provide a basis for pointing fingers and finding fault.

The TQM problem solving process uses fundamental statistical methods as a tool to interpret and control the current performance of a measured process. Through properly interpreted statistical data, a manager can begin to pinpoint the causes of problems. With an understaning of problem causes, the manager can control the amount of variance in the process, and implement improvements.

Each construction project is a <u>unique</u>, <u>dynamic process</u> typically spanning over several years; whereby, ideas are transformed into a facility when the work accomplished in <u>sequenced</u> <u>phases</u> (Scoping, Design, Procurement, Construction, and Start-up) is supplied to the next phase. It is well accepted that the decisions made in the early scoping and design phases have the greatest influence on project cost and success as a whole[17]. Consequently, TQM efforts to measure and improve

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[17]"Input Variables Impacting Design Effectiveness", <u>Constrution Industry Institute</u>, Publication 8-2, Jul 1987, p. 2.

the performance of these early phases will have the greatest potential rewards, and must be done.

However, some errors, omissions and mistakes in scoping and design phases are often times not discovered until several months or years later in the project process, during the construction and start-up phases. When we measure the performance of latter project phases, we are measuring all phases of a project both early and latter. The scoping and design constraints found during construction and start-up phases should be feed back to the suppliers of these inputs for future improvements. Unfortunately, due to the unique, sequenced nature of the project process, these improvements will generally come to late to improve the current project. These improvements, however, can be maintained to improve the overall performance of future projects that the Owner, Designer and Constructor undertakes. The dynamic nature of the construction process reinforces the need for customer and supplier interaction, process measurement and continuous improvement. Chapter Two and Four present a system for measuring and statistically examining the performance of on-site construction activities/processes as a basis for continuous project quality and productivity improvement.

1.1.8. CONTINUOUS IMPROVEMENT

TQM is a customer driven strategy based on continuous improvement in performance measured in terms of quality, cost, and schedule. Constant improvement occurs when management takes steps to - (1) maintain and incrementally improve current procedures and methods through process control oriented thinking, and (2) support major innovations with sufficient time, energy and money. A manager satisfied with the current status quo is sure to fall behind the competition.

The key to achieving incremental improvements is process control and improvement. Each on-site construction activity is a distinct process with defined procedures for the management of construction inputs (people, skills, materials, tools, equipment, information, place and energy), and with defined construction methods for transforming the inputs into an output that meets the project plans and specifications (requirements). Figure 1-3 shows the Triple Role/Input-Output diagram for on-site construction activities. Field Management is the customer of the activities units of work in place, and the Labor Force is the customer of the construction inputs.

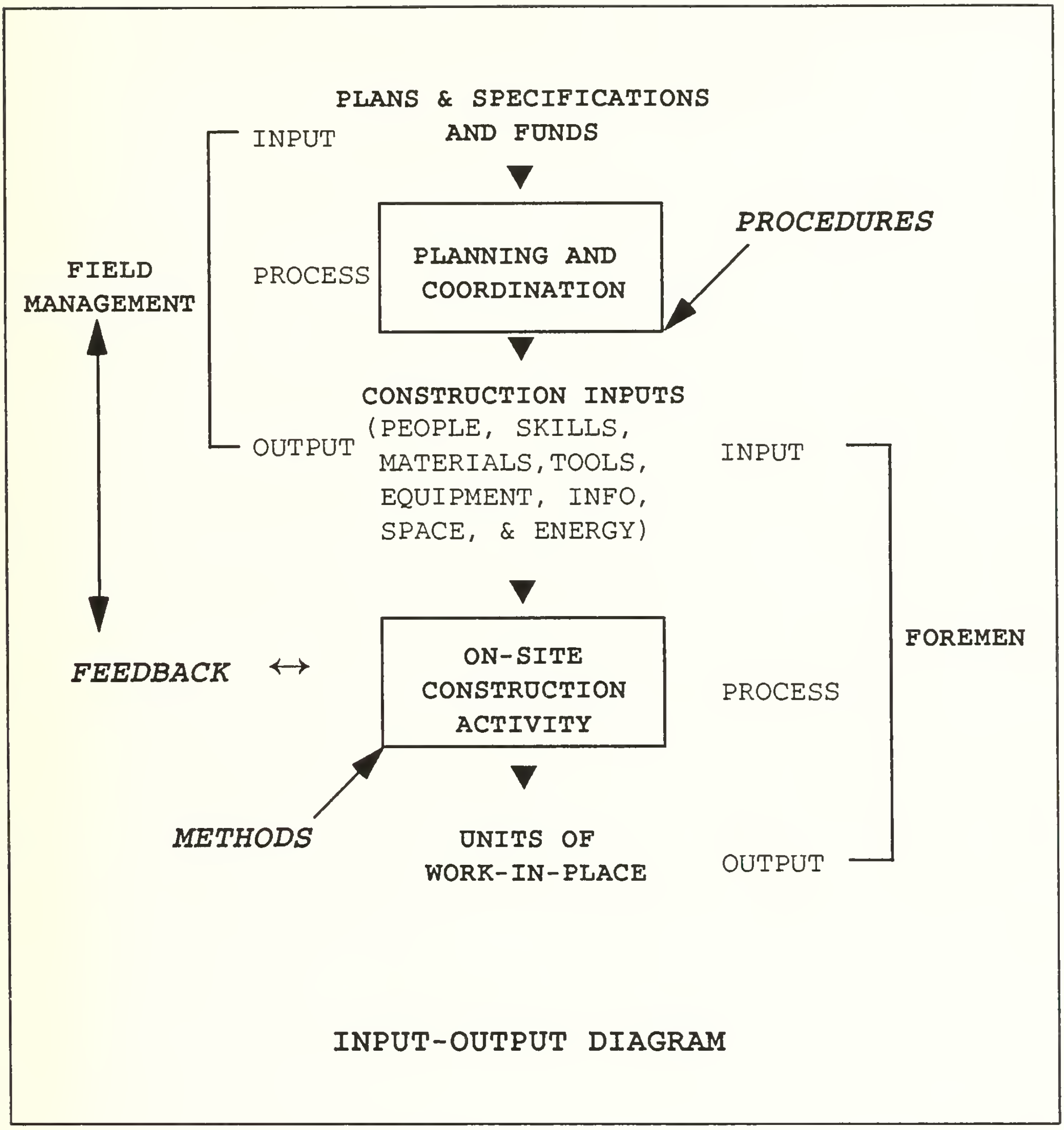

Figure 1-3 Juran's Triple Role Concept for On-Site Construction Activity Process

Continual improvement in the quality of on-site construction activity procedures and methods aimed at better satisfaction of the customer at the next stage will result in less rework, fewer delays and mistakes, and better use of construction inputs. Consequently, constant improvement in the quality of the construction activity process leads to decreased cost of quality and increased productivity. Quality in construction is associated not only with the materials and final product, but also with the way people work, the way tools and equipment are operated, and the way systems and procedures are dealt with.

Improvements in quality will lead to increased productivity, the only question is where to begin the improvements. Solving today's crisis only to fight a similar battle tomorrow, or eliminating an irritant is not improving the process; it is simply putting out fires. Only through process-oriented thinking and statistical analysis can we begin to understand the true causes of problems. When we understand the nature of the causes, we can expend effort to improve the process.

Process-oriented thinking is achieved in construction when- (1) we place as much emphasis on the process of the construction activity as we do on the results, and (2)

when we learn to recognize the difference between the symptoms and the causes of problems. The construction industry is results oriented. All too often, contractors bid projects based on estimates, measure the difference between the estimated and actual cost, and if a negative balance (symptom) exits, we attempt to justify our mismanagement on hunches. Rarely do we invoke process-oriented thinking to search for the real causes of the problems that lie within the process.

1.2. DEMING/SHEWHART PDCA CYCLE

The Deming/Shewhart Plan-Do-Check-Act (PDCA) Cycle[18] shown in Figure 1-4 is an essential tool for achieving process improvements, and ensuring that the benefits of improvements last. The "Plan" is a complete study of the current situation, during which- (1) data is gathered, (2) problems are analyzed using statistical methods, (3) causes are identified, and (4) solutions are planned. The "Do" is the implementation of the planned improvement on a pilot scale. The "Check" is the verification and confirmation that the plan achieved the desired improvement without adverse side effects. The "Act"

[18]Deming, p. 88.

means to prevent recurrence of the problem by standardizing the improvement as a new practice to improve upon through the next plan step. "The PDCA Cycle goes round and round[19]."

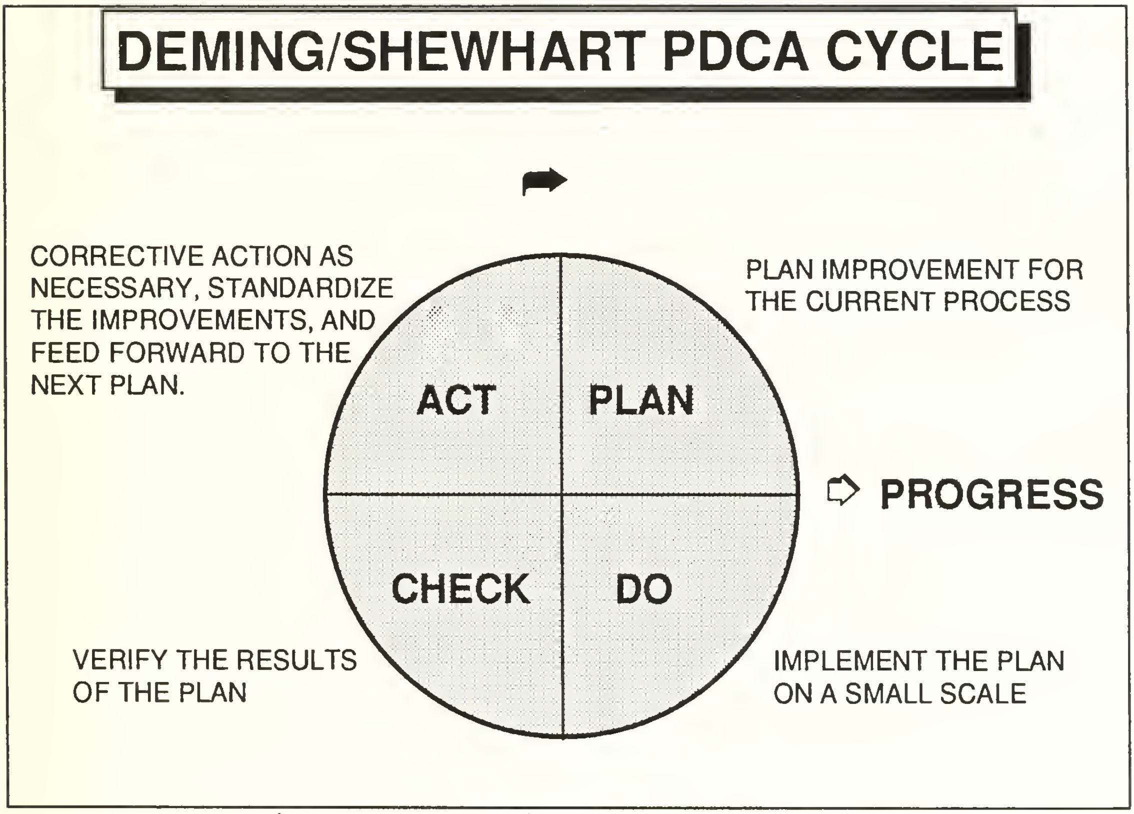

Figure 1-4 Deming/Shewhart PDCA Cycle

By continually turning the PDCA Cycle, both managers and workers are constantly challenged to reach new heights of improvement. Figure 1-5 demonstrates how a

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[19]Imai, p. 63.

proposed solution becomes a standard[20] to prevent a recurrence of the problem.

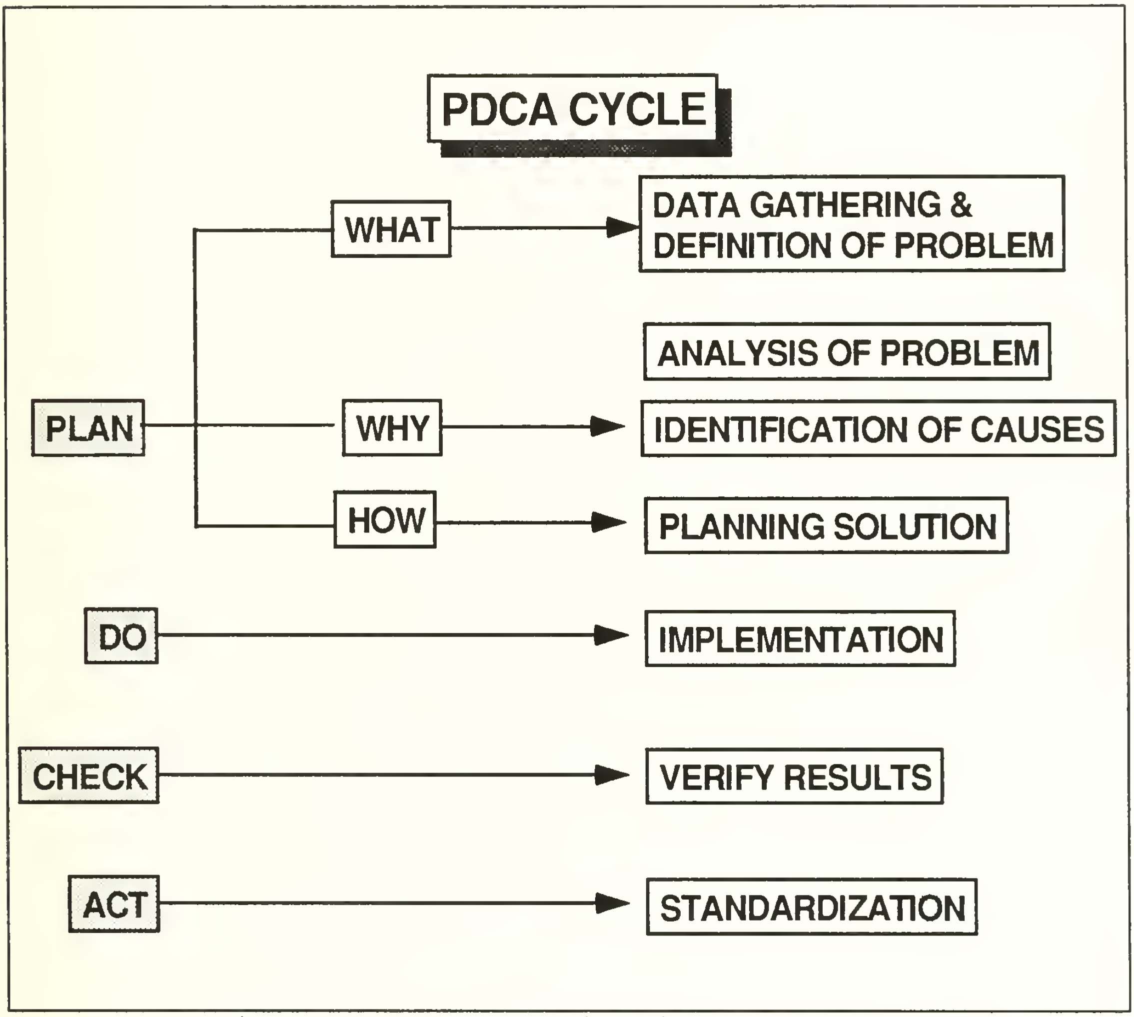

Figure 1-5 Standardization of Improvement

The remainder of this report describes how to apply the PDCA Cycle to improve the quality and productivity of on-site construction activities.

[20]Imai, p. 76.

2. CHAPTER 2

PLAN

2.1. PEOPLE AND PDCA FOR PRODUCTIVITY IMPROVEMENT

Successful on-site construction productivity improvement programs embody the blending of "people" and "techniques." TQM philosophies presented in Chapter One are the basis of the "people" side of a productivity improvement program. The "people" aspects of TQM create an environment where commitment to improvement and teamwork thrives. Remember, this commitment can only be generated after top management successfully demonstrates a sincere concern for people at all levels, and removes the barriers that create adverse relations so common in today's construction climate. The "techniques" side of productivity improvement is based on a plan-of-action for the implementation of a step-by-step procedure to achieve improvement. The Deming/Shewhart Plan-Do-Check-Act (PDCA) Cycle provides a plan-of-action for achieving productivity improvements in on-site construction activities.

Improvements are sought, found and implemented through the PDCA problem-solving process. The steps included in the "Plan" phase of the PDCA Cycle include

(1) data gathering and definition of problem, (2) problem analysis through statistical methods, (3) cause identification and (4) planning for a solution. Management's ability to identify and plan solutions to problems that impede productivity is dependent upon the ease and accuracy with which feedback data from the field can be collected and interpreted.

2.2. NEED FOR BETTER FEEDBACK DATA

2.2.1. CURRENT METHODS OF OBTAINING FEEDBACK DATA

Construction management generally employs both informal and formal data gathering methods for assessing the effectiveness of on-site construction activities[1]. The informal methods simply include the observations and feedback that management obtains through job-site tours, and informal "How is it going?" communication with project personnel. Although informal communication demonstrates management's concern and willingness to listen to the lower levels of the hierarchy, informal data gathering is often misleading. The labor force has learned not to be caught unproductive, and field

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[1]Clarkson H. Oglesby, Henry W. Parker, and Gregory A. Howell, Productivity Improvement in Construction, (New York: McGraw-Hill Inc., 1989), p. 134.

supervisors often fear the possible repercussions of forwarding bad news to upper level management.

Formal assessment methods most frequently used by construction managers are schedule and cost control reports. These formal assessment methods provide management with an opportunity to improve productivity through the application of the PDCA process mentioned earlier. Unfortunately, as pressure from a late schedule or budget overrun builds, management will often use schedule and cost control information to judge the performance of the labor force and field supervision. Instead of using this information for improvement, management may blame field supervisors for poor performance, and hold them accountable for all deficiencies in the construction process. This is unfair, as many of these cost and schedule deficiencies are due to failures in the "system" for administrative project support. Delays or inadequacies in schedules, and tools, materials, equipment and information constraints lead to low levels of productivity and poor morale. Since field managers have very little control over administrative support functions that adversely affect their productivity, they will resent management for using cost control information for deciding

performance. To stay clear of management's pressures, field managers will often report less than accurate information. Altering of cost and work completed figures for accounts that are in trouble may be the only method field supervisors have for saving themselves from an unjust punishment.

A cost control system incorrectly used may deceive rather that inform management, and lead to conflicts, less-efficient operations and strained relationships among project personnel[2]. Current formal assessment methods are results oriented rather than process oriented. They may alert management when the project is behind schedule or over cost, but schedule and cost reports seldom provide management with hard data to pinpoint the causes of the deficiencies in the process.

2.2.2. PROCESS ORIENTED FEEDBACK

Before we can improve the quality and productivity of on-site construction activities, we must look for a different way of measuring the performance of the activity process. As shown in Chapter One, this system must provide a "unit of measure" and a "sensor." Also, the unit of measure should provide a standard for performance that expresses the customer's needs and

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[2]Oglesby, p 33.

provides a basis for improvement. Field Management has requirements for the quality, schedule and cost of each activity, while the labor force has requirements for proper support of construction inputs (see Figure 1-3).

The next section will present a system for obtaining feedback on the performance of construction activity processes. This system entails a modification of current labor productivity measurement techniques to acquire data about the performance of construction activity procedures and methods. The modification entails the separation of time lost due to system delays from actual work-hours used to produce work in place. System delays are due to the procedures for support of construction inputs; where as, actual work hours are the result of construction methods. This modified productivity measurement system provides two units of measure, called "Crew True Unit Rates" and "Lost Time," that can be used as a basis for planning improvements in construction activity procedures and methods.

2.3. PRODUCTIVITY MEASUREMENT TECHNIQUES

2.3.1. ACTIVITY UNIT RATES

Since the major cost variable on a construction project is labor productivity, a contractor will want to measure work-hours and quantity of work in place as a major element of a cost control program[3]. Labor productivity, also called activity "unit rate," is "work-hours performed per units of work completed."[4] The dividing of work-hour information collected from daily or weekly time cards by the units of work accomplished for a given construction activity enables management to evaluate the efficiency of an activity. Activity unit rates are typically reported in daily, weekly or monthly periods.

2.3.2. LOST TIME AND CREW TRUE UNIT RATES

Activity unit rates may contain the efforts of more than one crew, and contain all work-hours including those lost due to delays. As such, it is difficult to fix responsibility when unit rate figures are less productive than planned. Unit rates should be calculated for each

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[3] "Project Control For Construction", Construction Industry Institute, Publication 6-5, (Sep 1987), pp. 6-7.
[4] "Productivity Measurement: An Introduction", Construction Industry Institute, Publication 2-3, (Oct 1990), p. 2.

separate crew, and lost-time hours excluded from the unit rate calculation. Otherwise, the productivity of an individual foreman will suffer due to performance and delays beyond his control. By explicitly counting lost-time hours separate from work-time hours, contractors finally have the means of collecting data that points directly to methods that will improve construction productivity[5]. Measurement of lost-time hours will enable management to identify problems in the system and procedures for administrative support of construction activities, and set priorities for corrective action.

Crew "true" unit rates, (calculated by dividing the actual man-hours worked by the units of work accomplished), provide a true measure of crew and construction method performance. The separation of actual work-time from lost-time allows a contractor to place responsibility, not blame where it belongs. Management must accept responsibility for time lost on the job due to "system" administrative support delays. Similarly, foremen must accept responsibility for their crew's true unit rate[6].

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[5]Louis Edward Alfeld, Construction Productivity, (New York: McGraw-Hill Inc., 1988), p. 65.
[6]Ibid., p. 66.

2.4. COLLECTION OF DATA AND PROBLEM DEFINITION

2.4.1. COLLECTION OF DATA

The amount of time lost due to delays can be measured through (1) Foremen Delay Surveys, (2) Work Sampling and (3) accounting of lost-time on daily time cards. While the first two methods have their merits, Alfeld[7] has developed a clever method for counting lost-time hours. This is accomplished through a simple modification of a standard foreman's time card as shown in Figure 2-1. The foreman reports the total work hours expended on an activity by each individual on the crew. The foremen then sums the total payroll hours for each individual and reports this in the "Total" column. The next step is to sum the total work hours vertically for each activity, and report this quantity in the "Total Work Hours/Activity Code" row. The foreman then reports the amount of lost-time hours for each activity corresponding to the causes shown in the "Lost Time Hours" column. Subtract the lost-time hours from the "Total Work Hours/Activity Code" row to arrive at actual work-time hours for each activity. This modified time card will undoubtedly require more time and effort to

[7]Ibid., p. 64.

complete, and foremen may object to the added paperwork burden. Formen must be convinced that this information will be used to help solve their problems rather than be held against them.

2.4.2. PROBLEM DEFINITION

The modified time card provides for much greater accuracy and detail in reporting, and allows management to pinpoint and define the major sources of delay problems. System procedures for support of construction activities, are the main causes of delay problems. When properly applied, lost time reports will help foremen by focusing top management attention on constraint problems that prevent his crew from being productive.

True unit rates can be measured for any activity. If comparisons are to be made with the project's estimate, then the activity should be consistent with the work breakdown structure or code of accounts of the project estimate[8]. Also, the units of measure used for reporting quantities completed should be consistent with the units used in developing the activity estimate. To ease the reporting process, these units should be simple, easy to identify and accurate. To be accurate, the level of

[8]CII, Publication 2-3, p. 6.

effort to complete a unit of work in place must be constant through the entire duration of the activity.

TIME CARD	ACTIVITY CODE						
Foreman:____________ Crew Number:________ Date:________________ Employee Name							Total
Total Work Hours/ Activity Code							
(-) Lost-Time Hours 10 Rework Design Error 11 Rework Change Order 20 Wait for Materials 21Wait for Information 22 Wait for Tools 23 Wait for Equipment 30 Other							 (-) (-) (-) (-) (-) (-) (-)
Work-Time Hours							

Figure 2-1 Foremen Time Card With Lost Time

2.5. PROBLEM ANALYSIS AND IDENTIFICATION OF CAUSES

2.5.1. ANALYSIS OF PROBLEM THROUGH STATISTICAL REPORTS

Data gathered from the foreman's time cards and quantities completed reports are compiled daily or weekly to generate statisticl feedback reports. The generation and use of effective feedback reports sets the stage for identification of problem causes and corrective action. Feedback reports can take many forms, but they should be easy to interpret, timely, accurate and appropriate for the level of management intended. Figures 2-2 through 2-6 are sample statistical Pareto and Line Graph Charts.

2.5.2. IDENTIFICATION CAUSES

Lost time is a measure of managements effectiveness. The Lost Time Pareto Chart shown in Figure 2-2 pinpoints the source of problems in the project's system and procedures for administrative support. At a glance, everyone can see that the two or three largest bars shown in Figure 2-2 account for the majority of the Lost Time. This follows the *Pareto Principle,* which is the phenomenon whereby, in any population of factors that contribute to a common effect, a relative few of the contributors account for the bulk of the effect[9].

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[9]Juran, p. 331.

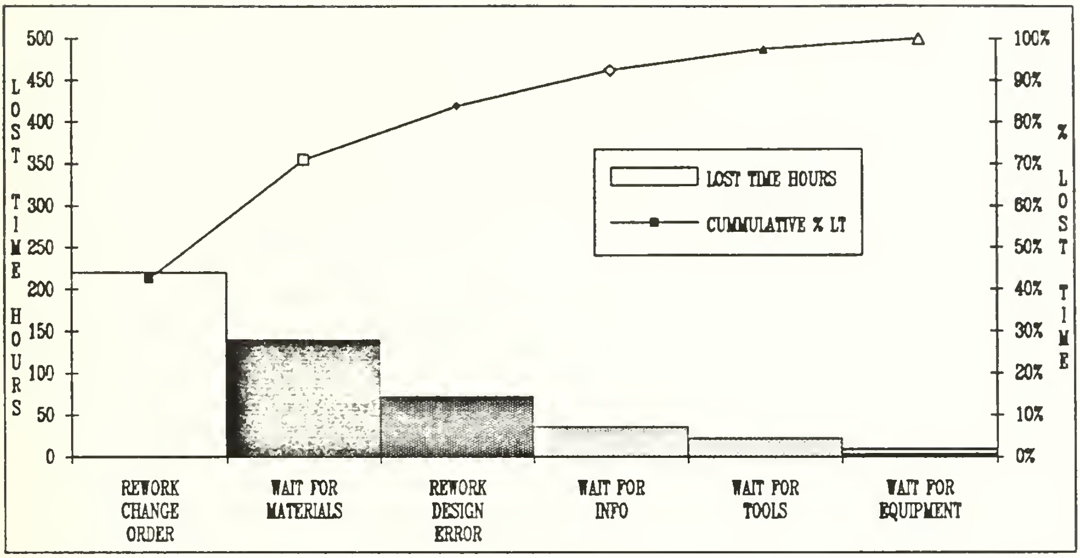

Figure 2-2 Weekly Lost Time Pareto Chart (Before Improvement)

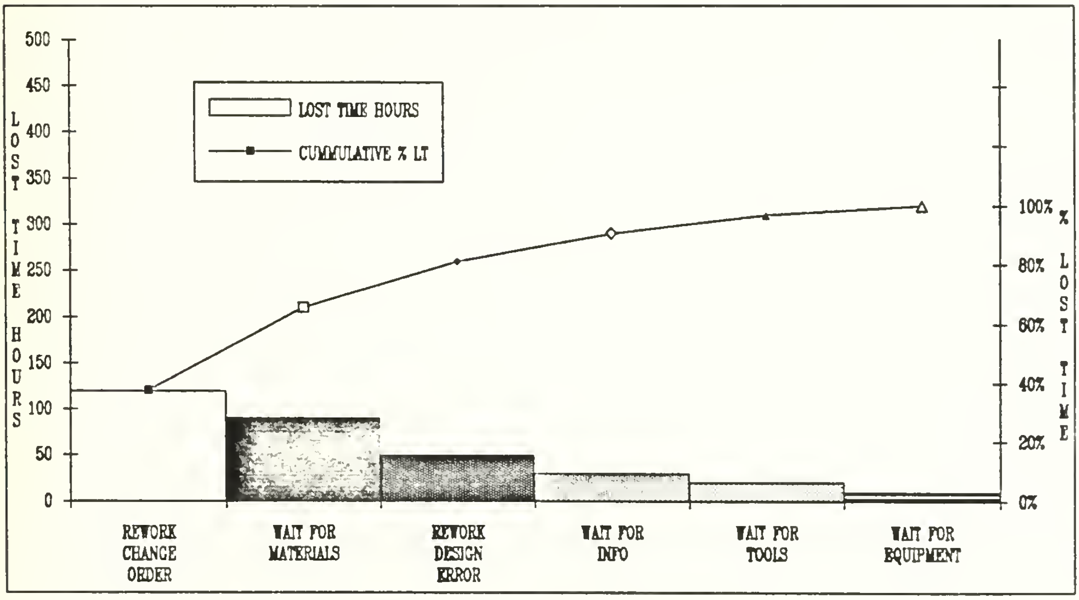

Figure 2-3 Weekly Lost Time Pareto Chart (After Improvement)

The value of a Pareto Chart is that it indicates the "vital few" Lost Time factors that are most prevalent, and therefore deserve concentrated efforts for improvement[10]. The Lost Time Pareto Chart is very useful in drawing the cooperation of all concerned, and establishes a priority for corrective action. Experience has shown that it is easier to reduce a tall bar by half than a short bar to zero[11]. Figure 2-3 shows the potential for reduction of Lost Time if Field Management takes concentrated corrective action to reduce by half the bars for both rework due to change orders and waiting for materials. Removing administrative support constraints improves the construction activity process, and improves the productivity and morale of the work force.

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[10]Kaoru Ishikawa, Guide to Quality Control, (2d ed; New York: Asian Productivity Organization, 1982), p. 45.
[11]Ibid.

Figure 2-4 is a graphical display of a single crew's true unit rate productivity during the accomplishment of a single activity. With a little training, each foreman can easily develop manual line graphs for their most significant activities. Foremen can use the line chart of Figure 2-4 to pinpoint the occurrence of productivity fluctuations so that the causes of the fluctuations can be identified. Thus, good productivity methods can be standardized, and low productivity methods eliminated.

Figure 2-5 is a line graph showing the Five Day Moving Average of the crew's productivity. Points for this line graph are obtained by averaging the true unit rate productivity of the current day plus the productivity of the past four days. As the true unit rate data for the next day is obtained, that data is added to the existing data, and the data for the oldest or least current day is deleted. Moving averages can be averaged over any time frame (n days). The value of n is often selected to cover a work week (n=5) so that the productivity from each day of the week is always included[12].

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[12]CII Publication 2-3, p. 11.

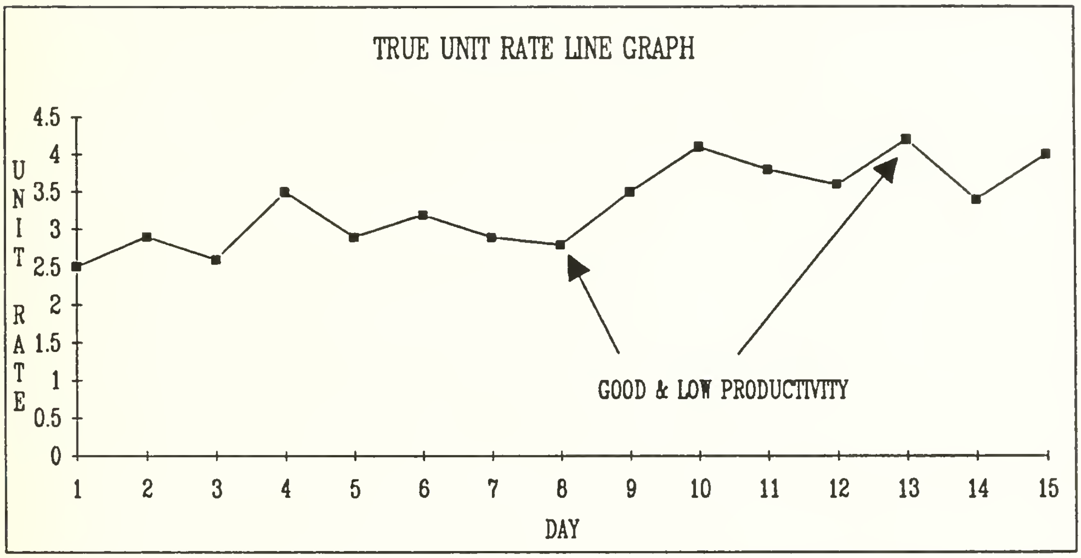

Figure 2-4 Line Graph Chart of Daily Crew True Unit Rate Productivity

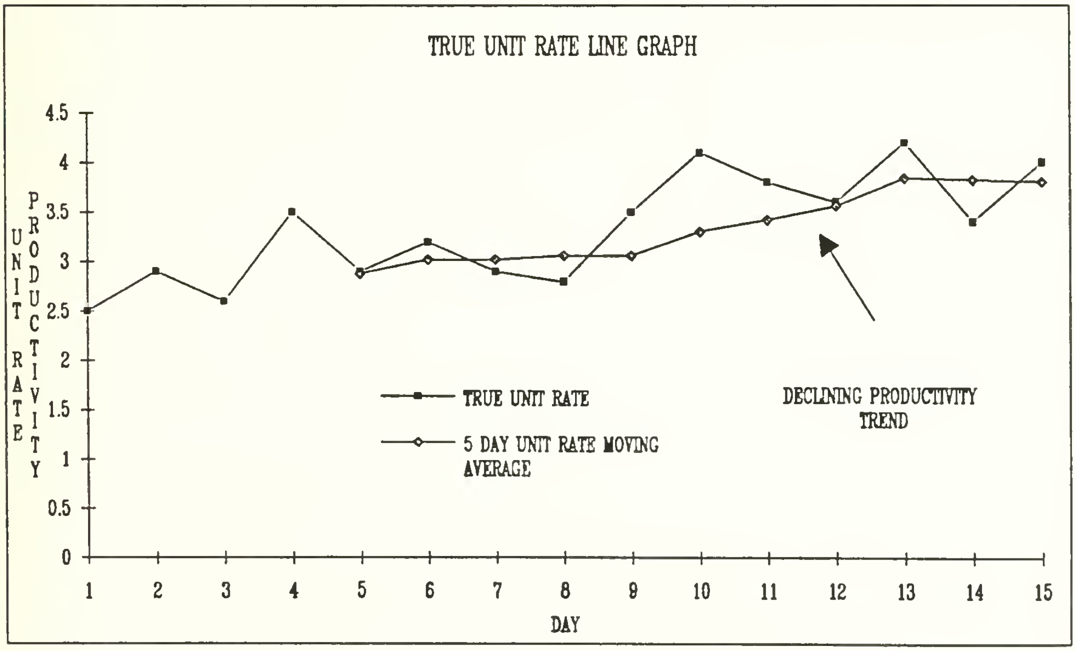

Figure 2-5 Line Graph Chart of Five Day Moving Average Productivity

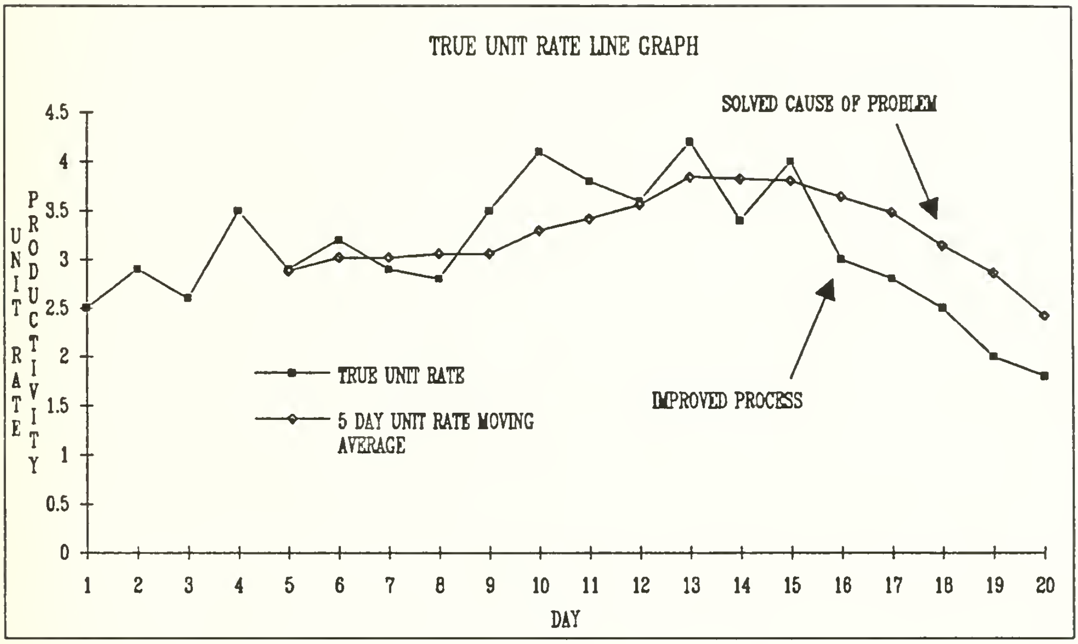

Figure 2-6 Line Graph Chart of Five Day Moving Average Productivity (After Improvement of Method Process)

Moving average line graphs enable the Foreman to see the "trends" in his crew's true unit rate productivity. The value of trend data is that it enables the Foreman to predict the crew's productivity, and implement corrective action when the trends show a need for improvement. Thus, corrective action measures can be taken before it is too late. By understanding the relationships shown in trends, the Foreman can analyze the outcomes of changes implemented in activity methods. Changes in activity methods and procedures that produce positive results can be standardized, and changes that are ineffective can be identified, and eliminated.

For example, an alert foreman who studies Figure 2-5 can easily see from the Five Day Moving Average that his crew's productivity is progressively declining. He can study the Daily True Unit Rate curve to pinpoint the days where productivity was poor and good, and find the factors that caused the fluctuation. Once he understands the causes of productivity variance, he can work to alter crew methods to improve productivity. Figure 2-6 shows the potential improvements in crew productivity with the identification and elimination of productivity variance. This report will require extra effort by the foreman, but

it does provide the foremen a basis from which to make informed improvements in activity methods.

2.6. PLANNING SOLUTIONS THROUGH TEAM APPROACH

CONSTRUCTION COMPANY TQM ORGANIZATION

A construction company's TQM Organization will depend upon the TQM approach selected, existing functional organization, and people involved. The purpose of the organization is to develop, communicate, implement, and monitor TQM efforts. The organization provides leadership and direction to ensure overall company quality improvement goals and objectives are met. However, the organization should be developed in such a manner that everyone in the company remains responsible to measure and continually improve quality within their area of responsibility.

Typically, a TQM organization will consist of an Executive Steering Committee, Departmental Steering Committees, Functional/Project Teams, Cross Functional Teams, and Task Teams. Each committee or team has a chairperson or team leader who is also a member of the committee/team that is one level higher in the organizational hierarchy. Thus, committees and teams are

interlocking through managers and supervisors so that improvement efforts can be coordinated[13].

Membership on a team is a part time job, except the chairperson of the Executive Steering Committee. The chairperson should be thoroughly familiar with TQM concepts and posses superior interpersonal skills. The Executive Steering Committee is composed of the companies top executive managers and departmental managers with horizontal lines of communication. Departmental managers are typically the chairpersons for the Departmental Steering Committee that is composed of the top managers of each operating group within the Department. These so called operating groups can be specific construction projects that the company is managing. Functional/Project Teams are composed of the key managers of operating groups/projects within a department. Cross-functional teams can be established at any level to address unique problems that cross functional boundaries (i.e., involve different work groups/projects or departments). Management at any level can commission a task team to address specific problems or opportunities for improvement.

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[13]"Quality Management Organizations and techniques", Consturction Industry Institute, Source Document 51, (Aug 1989), p. 31.

The Executive Steering Committee establishes the priorities for major corrective action and improvement efforts that are in line with the company's overall goals. The Pareto principle discussed in section 2.5.2 enables management at each level to focus attention and efforts on the biggest and most important problems first, then the next and so on.

PROJECT TEAMS AND TASK TEAMS

Implementation of prioritized corrective action and improvement efforts is carried out through the use of the PDCA cycle at each level within the construction company's organization. The scope of the implementation plans become more specific with each descending level in the organizational hierarchy. The greatest benefit of the team approach is the major gains in quality and productivity that result from the pooling the skills, talent, support, and ideas of a group to solve problems[14]. A properly supported and trained team can efficiently tackle complex problems, and come up with effective and permanent solutions because the members of the team are closest to the problems. Consequently, project teams and task teams provide the greatest potential for improvement

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[14]Peter R. Scholtes, The Team Handbook, (Madison, WI: Joiner Associates Inc., 1988), p. 2-7.

of a specific project's on-site construction productivity.

The project team can use Lost Time data collected to define and analyzed problems in the project's system. The Lost Time Pareto Chart shown in Figure 2-2 can be used to establish priorities for corrective action. The Project Team can then commission a task team to address specific system problems through the implementation of the PDCA problem solving cycle. Similarly, the project team should identify critical labor-intensive construction activities for True Unit Rate productivity measurement and analysis. The greatest return on the investment of time and effort to measure and analyze on-site activity processes through the statistical Line Graph and Control Chart techniques presented in this report come from the selection of long duration activities that are: (1) very repetitive and have a short cycle time, (2) performed by small crews, and (3) performed on many projects that the construction company handles. Almost without exception, the most significant work-hour activities also will be significant schedule-duration activities[15]. The proper selection of activities for process analysis allows sufficient time for the

[15]CII Publication 2-3, p. 6.

statistical techniques to pinpoint opportunities for improvement, and allows improvements to be implemented and refined on future projects. Once the project team selects an activity for process (productivity) analysis, the team should commission a task team to address the specific activity.

The job of task teams should be carefully explained, and their completion time specified[16]. Membership on task teams is assigned, and should cut across project organizational lines both horizontally and vertically to ensure that talents and knowledge required to solve the specific problem is present. Task teams can then use existing data and apply the PDCA problem solving process to develop and implement solutions and improvements to both the project's system and specific activity processes. The following are the elements of successful teams[17]:

> (1) Management support: Project Team provides guidance through clearly defined team mission statement, secures resources and clears a path for task team.
>
> (2) Member participation: Establish ground rules to encouraged full participation. Trained

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[16]Philip B. Crosby, <u>Quality is Free</u>, (New York: Mentor, 1979), p. 192.

[17]Scholtes, pp. 2-39 -3-19.

facilitator helps to keep the team on track. Team leader, facilitator and members fully understand their roles.

(3) Group training: Facilitator provides instruction in both humanistic (communications, group behaviors and decision procedures) and technical problem solving techniques (data collection, problem analysis, and solution development and implementation).

(4) Teamwork: Team members appointed to team work closely with the problem/process under study. Ideally, each area and level of employees affected by the problem/improvements should be represented. Members should contribute their knowledge, expertise and participation at all meetings. Every team member can and should make a contribution to the project, and no one member should be allowed to dominate the discussions.

(5) Problem Solving Approach: Team uses a well thought out PDCA improvement plan, along with group decision making, and basic statistical problem solving techniques to:

- identify root-causes based on data
- plan permanent solutions
- implement solutions on small scale
- verify results
- standardize successes
- refine improvement through next PDCA cycle

PLANNING SOLUTIONS

After a task team finds root-causes to problems, the team should then brainstorm alternative solutions. The alternatives should be evaluated based on feasibility of implementation. Feasibility analysis should address the following questions:

- Is the solution easy to introduce, implement, and maintain?

- What are the possible disadvantages, weaknesses or negative consequences?
- Anticipated resistance to solution?
- Will organizational culture support solution?
- Skills, training and education required to implement solution?
- Resources required (money, people equipment, tools, and materials) to implement training and solution?
- How will change effect other processes?

The overall best solution should be selected and its implementation planned. Success will depend on how well the task team anticipated the resources needed to carry out the changes, how much training and preparation everyone receives, whether key leaders lend their support, and whether the cultural environment is ready for the change[18].

[18]Scholtes, p. 5-45.

3. CHAPTER 3

DO

The successful implementation of a planned solution requires three primary elements: (1) management support, (2) worker support, and (3) education and training. It is always best for a task team to carry out a small-scale or pilot study of the proposed change before making it wide-spread. Upon verification (check) that the change produced the desired results, the task team can then act to secure the three primary elements required to implement the change on a full scale basis.

Effective documentation and communication of successes with pilot programs is essential to winning the support of management and those affected by the change. Construction companies should have an established procedure for the review, approval, and implementation of task team solutions. The task team facilitator should assist the task team in developing a presentation to win project team support for the implementation and standardization of the solution on a project-wide basis. Improvements that prove to be successful on a project-wide basis and can be applied on a company-wide scale should then be reviewed by the company Executive Steering Committee.

Winning the support and participation of the work force involves communication and training. Teams implementing changes need to be aware of whom will be affected by the change, what jobs may be changed, and how people will be trained and qualified. People are naturally resistant to changes. This is why top management commitment and effective communication of the fundamental TQM elements described in Chapter One is the key step toward creating an environment where improvements are sought and welcomed. Quality improvement has no chance unless the individuals involved are ready to recognize that improvement is necessary[1]. Task teams must know and understand the ideas, questions, doubts, and fears of those impacted by the change. Keeping employees informed, and listening to their inputs is key to gaining their support and participation.

Upon successfully gaining the support and participation for the change, the people who are going to be affected by the new standards must be educated. A superior must educate his subordinate on a one-to-one basis through the actual work. Once the subordinate is educated in this manner, the supervisor should delegate

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[1]Philip B. Crosby, Quality is Free, (New York: Mentor, 1979), p. 81.

authority to him and let him have the freedom to do his job. In this way, management creates a situation in which everyone is well-trained, can be trusted, and need not be supervised excessively[2].

If everything is done according to the methods explained above, implementation should pose no problem. However, the team implementing the solution must be aware of changing conditions, and verify (check) that the solution continues to produce the desired results.

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[2]Kaoru Ishikawa, What is Total Quality Control?, (Englewood Cliffs, N.J.: Prentice-Hall Inc., 1985), p. 65.

4. CHAPTER 4

CHECK

4.1. PURPOSE

All too often, Field Management implements plans and changes to the construction process without adequately checking to verify that the desired results are being achieved. Before one can check to verify that a change in procedures or methods produced the desired quality features, the required objectives, goals, and standards must all be clearly understood. In the case of on-site construction activity productivity, the desired quality feature is to achieve the planned production rate within the planned quality, cost, and schedule. This Chapter presents a technique for answering the question -"what and how should Field Management check existing activity processes?".

Checking to verify that a planned and implemented process is meeting desired goals requires collection and analysis of process oriented data. As shown in Chapter Two, True Unit Rates and Lost Time provide feedback data on the performance of construction activity processes. What we must understand is that the performance of any

process is affected by an unlimited number of causes[1]. As seen in Figure 2-4, a single crew's True Unite Rate productivity will be dispersed from day to day. In other words, there will always be variability in the activity productivity due to causes affecting the process. This variability can be expressed by a statistical distribution. When we check therefore, we must be guided by the idea of distribution. The most convenient tool for the check purpose is the three sigma control chart invented by Dr. W. A. Shewhart[2].

A control chart sends statistical signals, which detect the existence of a *special cause* of process variation, or tell us that the observed variation is due to the fault of the system[3]. The system in which construction activities are carried out includes: (1) management styles, policies, and procedures for administrative support, (2) people (experience, skills, and motivation), (3) Safety considerations (4) weather considerations, and (5) customer and public relations. Special Causes are those that are outside the system, and

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[1]Kaoru Ishikawa, What is Total Quality Control?, (Englewood Cliffs, N.J.: Prentice-Hall Inc., 1985), p. 204.
[2]Ibid.
[3]W. Edwards Deming, Out of the Crisis (Massachusetts Institute of Technology Center for Advanced Engineering Study, Cambridge, Mass, 1986), p. 310.

can be attributed to a specific group of workers, specific machine, or to a specific local condition. Causes of variation that are the fault of the system are called *common causes*. Discovery and control of a special cause of activity productivity variation is the responsibility of the Foremen, and continuous reduction of common causes of variation is the responsibility of the superintendent.

A stable process is one with no indication of special causes of variation, and is said to be in *statistical control*[4]. A construction activity process that is in statistical control can produce a predictable quantity of work in place at a predictable quality, cost, and schedule. In other words, management can confirm the capability of the activity process. A process that is in control also provides a basis for improvement through continuous reduction of variation.

Control charts commonly used in manufacturing processes are the Mean-Range ($\bar{x}$ - R) control charts and the moving Mean-Range ($\bar{x}$ - R) control charts. The moving $\bar{x}$ - R control chart is used by many organizations involved in continuous batch processes; such as, manufacturing of steel, aluminum, paints and chemicals.

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[4]Deming, p. 321.

Detailed construction activities that are broken down and measured by a single construction product; such as, linear feet of pipe, or cubic yards of concrete placed and finished, may be thought of as batch processes. At the end of each day, the units (single construction product) of work in place can be measured for a detailed activity, and the True Unit Rate in hours/unit calculated. The remainder of this chapter describes a method of using moving $\bar{x}$ - R control charts to check the productivity performance of detailed on-site construction activities.

4.2. MOVING MEAN-RANGE CONTROL CHARTS

4.2.1. CHART CONSTRUCTION

Two measures of a process are critical: its position (mean) and its variability (range)[5]. The control chart shown in Figure 4-1 provides a graph of the true unit rate productivity moving mean ($\bar{x}$) and range (R) with control limit lines. The mean portion of the chart shows any changes in the mean value of the activity productivity, while the range portion shows any changes in the dispersion of the activity productivity. Range is a practical measure of process variation[6].

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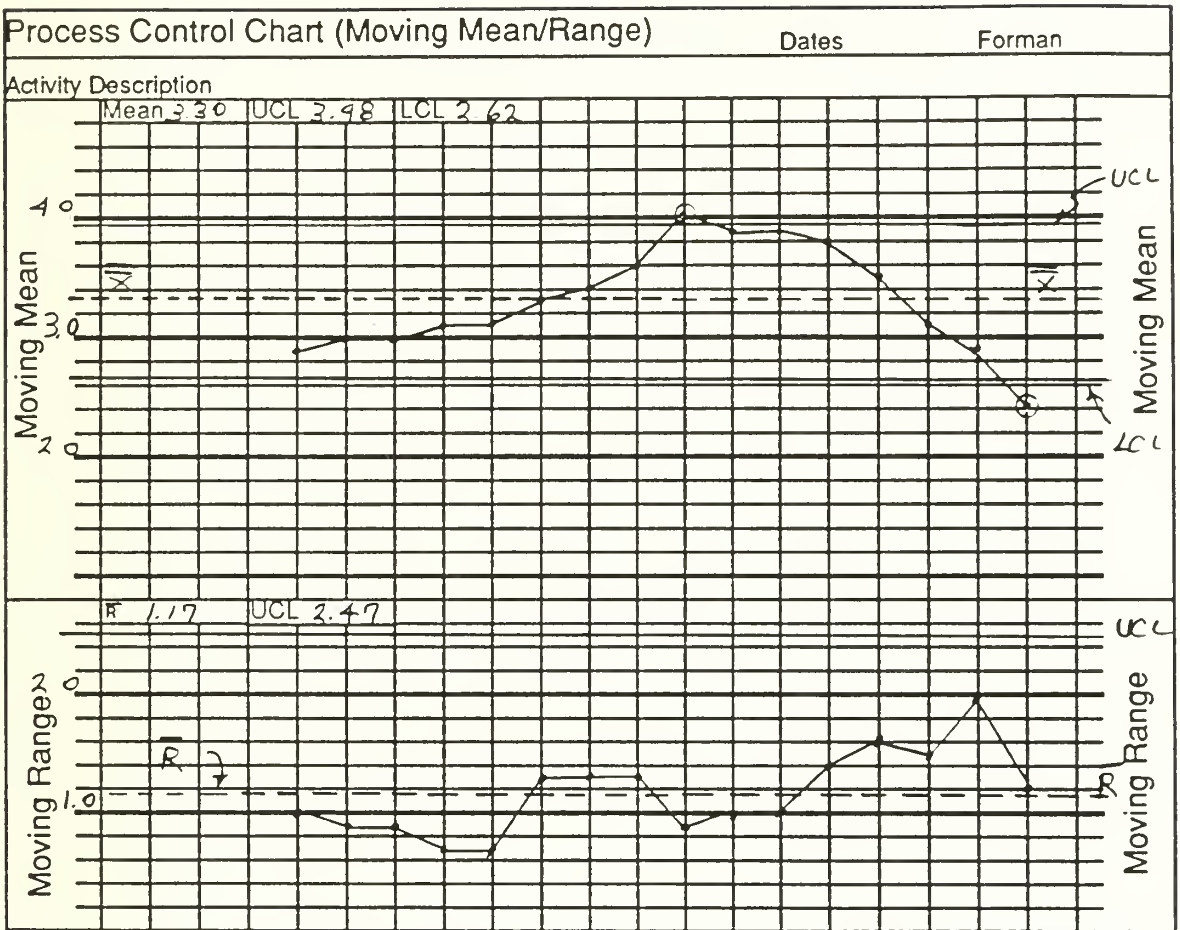
[5]Mal Owen, SPC and Continuous Improvement, (Bedford, UK: IFS Publications, 1989), p. 103.



Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Day
x	25	29	2.6	3.5	2.9	3.2	29	2.8	3.5	41	38	4.0	4.4	34	40	30	28	25	20	1.8		x
$\bar{x}$					2.9	30	3.0	3.1	31	3.3	34	36	4.0	39	39	38	35	31	29	24		$\bar{x}$
R					1.0	0.9	0.9	0.7	0.7	1.3	1.3	1.3	0.9	1.0	1.0	14	1.6	1.5	20	1.2		R
Notes																						Notes

Figure 4-1 True Unit Rate Moving Mean-Range Control Chart

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[6]Ibid., p. 70.

The Limit lines indicate the statistical dispersion of data, and show if special causes (abnormal situation) exist[7]. There are three kinds of Limit Lines: the Upper Control Limit (UCL), the Central Line ($\bar{\bar{X}}$ or $\bar{R}$), and the Lower Control Limit (LCL). The guidelines for the construction of control limits are based on the properties of the normal distribution curve shown in Figure 4-2. The wider the base of the distribution curve, the larger the variability, and the larger the standard deviation (s or σ).

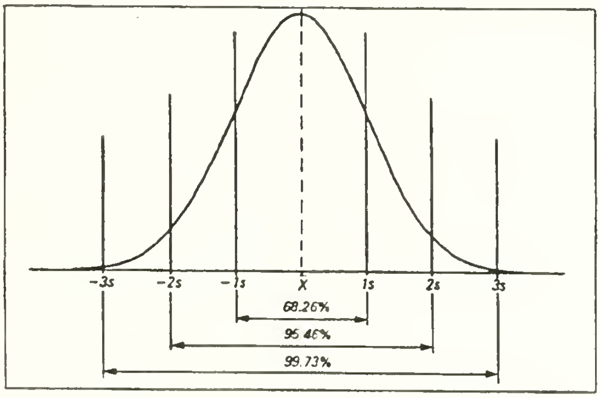

Figure 4-2 Normal Distribution Curve

[7]Kaoru Ishikawa, Guide to Quality Control, (2d ed; New York: Asian Productivity Organization, 1982), p. 62.

For any normal distribution, 99.73% of the readings/measurements fall with ± 3 standard deviations (s, also called sigma σ) measured outward from the central line[8] ($\bar{\bar{x}}$). By rotating the normal curve of Figure 4-2 so that the lines of symmetry are horizontal, the control limits showing three standard deviations and the central line are established.

Control charts require three stages: (1) Measurement (2) control through process analysis to eliminate special causes, and (3) improvement once the process is in control. The measurement stage makes use of True Unit Rate productivity data to develop the moving $\bar{x}$ - R graphs. The control stage is the basis of the CHECK phase of the PDCA cycle. Once the activity process is in statistical control, the capability of the implemented process can be confirmed and verified. The improvement stage is the basis of the ACT phase of the PDCA cycle. Continuous improvement means gradually reducing the base of the True Unit Rate distribution curve over time when the curve is symmetrically on the planned productivity rate for the activity process (i.e., productivity in proper position).

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[8]Owen, p. 106.

The True Unit Rate Moving $\bar{x}$ - R control chart shown in Figure 4-1 is composed of four primary sections: (1) administrative block, (2) moving True Unit Rate $\bar{x}$ graph, (3) moving R graph, (4) and the data block. The administrative block is used to document information about the activity, the crew and the methods used for future reference. The data block section is used to document the daily True Unit Rate dada, and the calculated moving $\bar{x}$ and moving R.

In carrying out the initial process analysis study for the check phase of the PDCA cycle, at least 20 data samples are required. The measurement, calculation and plotting of the moving True Unit Rate $\bar{x}$ follows the same process as the Moving Average Productivity graphs shown in Chapter Two. As with Moving Average graphs, Moving Mean graphs can be calculated over any time frame (n days). The value of n is called the sample size. A larger sample size smooths out the form of the plot, and makes it easier to see the effect of any genuine changes in the activity process. In this example, the sample size of 5 days was chosen. Moving mean is obtained as:

$$\bar{x} = \frac{\Sigma x}{n}$$

The calculated five day moving mean for day 5 is (2.5+2.9+2.6+3.5+2.9)/5 = 2.9 hours/unit. For each successive day, the first of the previous group is dropped, and the next in sequence is added. The true unit rate moving mean for the next five days is (2.9+2.6+3.5+2.9+3.2)/5 =3.0. Hours/unit, and so on. The moving true unit rate means are then plotted.

The moving range also is determined based on groups of five. Range = x (Largest) - x (Smallest) for the sample size (group) of five days. The True Unit Rate Range for day 5 is (3.5 - 2.5) = 1.0. The Range for the next day is (3.5 - 2.6) = 0.9, and so on. The moving Range values are then plotted.

4.2.2. CONTROL LIMITS

The central line for the moving $\bar{x}$ graph is called the grand mean ($\bar{\bar{x}}$). The grand mean is obtained as:

$$\bar{\bar{x}} = \frac{\Sigma\bar{x}}{k},$$ where k is the number of samples.

Therefore:

$$\bar{\bar{x}} = \frac{52.9}{16} = 3.30 \text{ hours/unit.}$$

The central line for the moving range graph is obtained by: $\bar{R} = \frac{\Sigma R}{k}$. Therefore:

$$\bar{R} = \frac{18.7}{16} = 1.17.$$

The UCL and LCL lines are calculated through the relationship involving A_2 and $\overline{R}$. This relationship is such that 3 standard deviations (σ) of $\overline{x} = A_2\overline{R}$, where A_2 is a constant that depends on the sample size n[9]. Therefore:

$UCL_{\overline{x}} = \overline{\overline{x}} + A_2\overline{R}$

$LCL_{\overline{x}} = \overline{\overline{x}} - A_2\overline{R}$

$UCL_R = D_4\overline{R}$

$LCL_R = D_3\overline{R}$; where D_3 and D_4 are also constants based on the sample size n. Values for A_2, D_3, and D_4 can be found in any statistics book, and are also shown in Table 4-1[10]. For sample sizes less than 7, D_3 does not apply; therefore, there is no LCL.

n	A_2	D_4	D_3
2	1.880	3.267	-
3	1.023	2.575	-
4	0.729	2.282	-
5	0.577	2.115	-
6	0.483	2.004	-
7	0.419	1.924	0.076

Table 4-1
Standard Statistic Constants

[9]Owen, p. 111.
[10]Ishikawa, Guide to Quality Control, p. 68.

The calculation of UCL and LCL lines for a sample size of 5 and the data shown in Figure 4-1 is then:

$UCL_{\bar{x}} = 3.3 + 0.577x1.17 = 3.98$ hours/unit

$LCL_{\bar{x}} = 3.3 - 0.577x1.17 = 2.62$ hours/unit

$UCL_{R} = 2.115 \times 1.17 = 2.47$

These control limits are then drawn on the respective charts.

4.2.3. CONTROL CHART INTERPRETATION

The example process analysis shown in Figure 4-1 shows that the activity process is unstable due to the existence of special causes (i.e., points outside the control limits). A process is in a controlled state when: (1) all the points of the control chart will lie within the control limits, and (2) point groupings do not assume a particular form (nonrandomness) even though they are within the control limits[11]. The four most common patterns of non-randomness are *runs*, *trends*, *periodicity*, and *hugging of control line*. A "run" is when seven or more points line up consecutively on one side only of the central line. A continued rise or fall in a series of seven or more points is considered a "trend." If the points show the same pattern of change; such as, rise and fall over equal periods of time, "periodicity" is said to

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[11]Ishikawa, Guide to Quality Control, p. 74.

exits. When points on the control chart stick close to the central line or to the control limit lines, it is called "hugging of the control line." There is abnormality if 3 out of 7 or 4 out of 10 points lie within zones drawn as follows:

(1) Zone next to the central line when a line is drawn between both the central line and the UCL, and the central line and the LCL.

(2) Zone next to the UCL or LCL, when a line is drawn at two-thirds the distance between the central line and the UCL or LCL.

Control charts enable management to determine if process variability is the fault of the worker or the fault of the system. The presence of special causes through any of the methods described above should alert the Foreman that specific activity methods, workers, tools or equipment may be the cause of the variance. The distance between the UCL and LCL limits corresponds to the base of the normal distribution curve, and is a measure of the amount of variance due to common causes that can be attributed to the system (i.e., management).

Control charts can identify the existence of special causes, but they do not tell us the source of the cause. Therefore, it is vital that the Foreman directly

responsible for the operation investigate the abnormality quickly before the trail grows cold[12]. The Moving True Unit Rate $\bar{x}$ - R control chart in Figure 4-1 shows that two points are abnormal because they lie outside the control limits. The low productivity ($\bar{x}$) value of 4.0 for day 13 is the mean True Unit Rate for days 9-13, while the high productivity value ($\bar{x}$) of 2.4 on day 20 is the mean True Unit Rate for days 16-20. Therefore, when the Foreman searches for the cause of the abnormal variance, he must look at potential special causes that affected productivity during the five day period. Special causes that lead to low productivity should be eliminated, while special causes that lead to high productivity should be standardized.

Continued identification and removal of special causes will eventually result in an activity process that is in statistical control. However, simply because the activity is in control, does not assure that the resulting central line is in proper position (i.e., at or above the planned unit rate productivity). If the process grand mean ($\bar{\bar{x}}$) is below the desired productivity, the Foreman and Field Management should work together to

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[12]Deming, p. 319.

implement changes to the activity methods. Improvement in activity methods can be achieved by: (1) elimination of operation steps, (2) combination of operations, and (3) reduction in operations. Take care during this adjustment to ensure that the changes do not send the process out of control.

5. CHAPTER 5

ACT

5.1. STEPS TO ON-SITE PRODUCTIVITY IMPROVEMENT

5.1.1. INTRODUCTION

The Act process of the PDCA cycle involves four distinct steps: (1) methods improvement through reduction of inefficient operations, (2) corrective action to eliminate special causes of process variation, (3) standardization of solutions to prevent recurrence of problems and achieve process control, and (4) continuous improvement of the process. The first three steps are executed by the team studying the process in the order presented. Upon successful completion of each activity, the team applies another rotation of the PDCA cycle to constantly reach new heights in productivity improvement. As will be presented in the latter part of this chapter, continuous improvement of on-site construction activity processes requires the combined efforts of everyone associated with the project. The successful application of these four steps will achieve both immediate and permanent productivity improvements.

5.1.2. REDUCTION OF INEFFICIENT OPERATIONS

The first step that the activity task team should take is the reduction of inefficient operations. The objective of this step is to eliminate, combine, or reduce unnecessary steps in the activity process. In other words, work smarter not harder. Traditional productivity methods improvement techniques; such as, 5-minute rating, process charts, flow diagrams, and crew balance charts should be used to help identify steps that are obviously inefficient. It is beyond the scope of this report to present these four techniques in their entirety; however, this topic is thoroughly presented in "Productivity Improvement in Construction" by Oglesby, Parker and Howell[1]. Each of these techniques can be applied quickly to help the team define, communicate and improve the current process. The team must take care not to get stuck on this step. The goal is to use a traditional improvement technique to make immediate improvements in the process by simply reducing the most obvious sources of waste and constraints. The team should then implement the improvements (eliminate, combine, or reduce operation steps), and then measure the

[1]Clarkson H. Oglesby, Henry W. Parker, and Gregory A. Howell, Productivity Improvement in Construction, (New York: McGraw-Hill Inc., 1989), pp. 171-239.

results to verify the success of the solution. The team has now reduced waste, improved productivity, and most importantly, defined the improved process. Further refinements can be made when the activity process is under a process analysis study.

5.1.3. CORRECTIVE ACTION

We apply corrective action to eliminate special causes of process variation at the source of the problems. Chapter Four presented a method of analyzing an activity process through Moving Mean/Range Control Charts to measure and detect the occurrence of special causes. Upon detection of a special cause, the team responsible for analyzing the process must again apply the PDCA cycle and plan a solution. The team should then implement the solution on a small scale, and verify the results. Continual identification and removal of special causes of variation will eventually produce an activity process that is in a state of statistical control (i.e., no special causes exist). Once corrective action solutions have been checked as successful, action is taken to prevent recurrence of the problems by standardizing the improvement on an activity-wide basis.

5.1.4. STANDARDIZATION

As mentioned in Chapter Three, the standardization of a change on a wide-spread basis requires the support of both management and workers, and training and education. Solutions that improve the productivity of an activity process should be standardized for all crews working on that activity. Because of the fast pace of construction activities, this action step should be taken as quickly as possible. To reap the full potential of improvements, successful activity procedures should be sufficiently documented and publicized for use on future projects. Crews tasked with completing an activity similar to one previously studied and documented should be encouraged to implement the most improved activity process, and be challenged to develop further refinements[2]. The use of previously documented activity procedures works best if the construction company has an effective pre-planning program[3] to outline the procedures for on-site activity operations.

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[2]Peter R. Scholtes, The Team Handbook, (Madison, WI: Joiner Associates Inc., 1988), p. 5-57.
[3]Oglesby, p. 119.

5.2. CONTINUOUS IMPROVEMENT

5.2.1. INTRODUCTION

Once an activity process is in control and the productivity central line in proper position (productivity equal to original estimate or better), the improvement process can be pushed effectively[4]. The Project team, task teams, and workers should then concentrate on continuous improvement through two functions. First, to maintain and incrementally improve current methods and procedures through standardization of improvements, and reduction of sources of common cause variation. Second, to support and encourage innovative methods improvement efforts to achieve major technological advances in engineering and construction processes. Figure 5-1 shows how the responsibilities for these two continuous improvement functions are perceived in Japan[5].

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[4]W. Edwards Deming, Out of the Crisis (Massachusetts Institute of Technology Center for Advanced Engineering Study, Cambridge, Mass, 1986), p 321.
[5]Masaaki Imai, KAIZEN The Key to Japan's Competitive Success, (New York: Random House Business Division, 1986), p. 5.

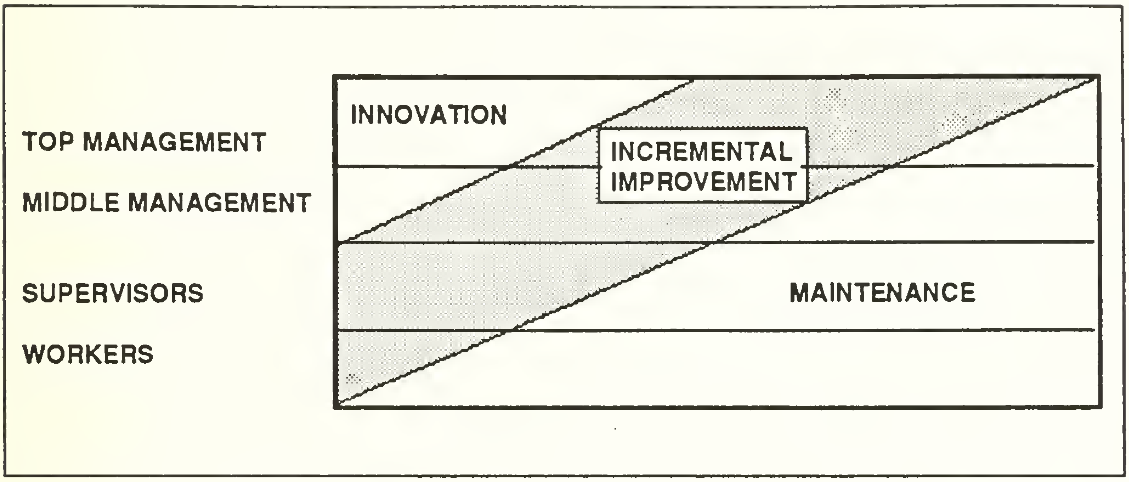

Figure 5-1 Job Functions for Continuous Improvement

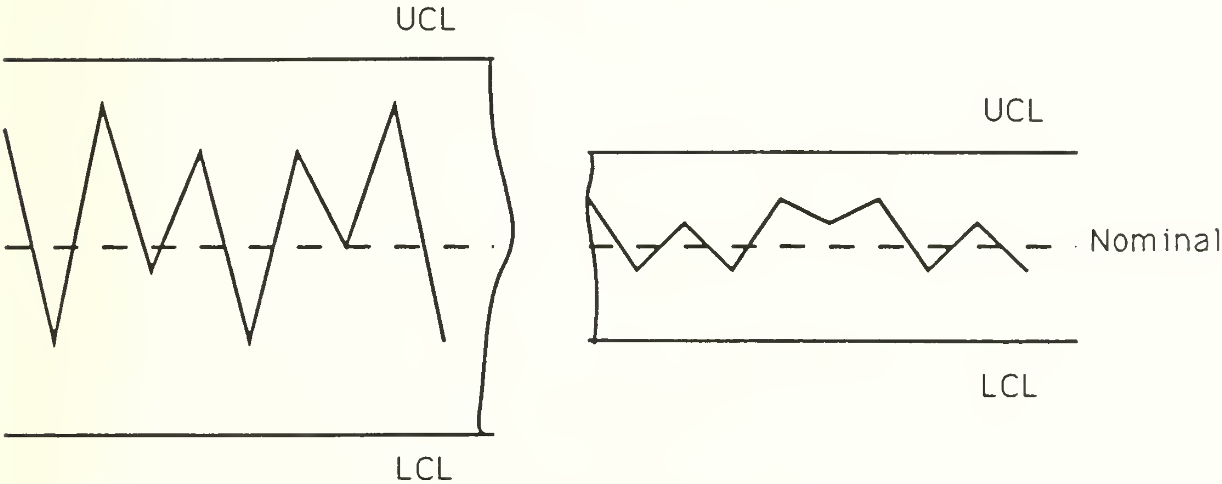

Figure 5-2 Effect of Incremental Improvement on Productivity

5.2.2. MAINTENANCE AND INCREMENTAL IMPROVEMENT

Maintenance refers to activities directed toward maintaining current technological, managerial and operating standards[6]. Incremental improvement refers to those activities directed toward improving current standards through reduction of sources of common cause variation. The key to maintenance is: (1) documentation of the current best standard operating procedures, (2) training on these procedures, and (3) review and revision of standards upon adoption of further improvements.

Incremental improvement occurs when the project team looks up stream at the system and procedures of on-site construction activity processes, and identifies and eliminates the root-causes of variation common to everybody on the job. Control charts can be used to conduct a process control analysis. The purpose of process control is to detect any abnormality in a process once the process has been standardized[7].

Through the control chart, we use information provided by the process to constantly reduce the variability about the central line[8]. The effects on

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[6]Imai, p. 6.
[7]Kaoru Ishikawa, Guide to Quality Control, (2d ed; New York: Asian Productivity Organization, 1982), p. 65.
[8]Mal Owen, SPC and Continuous Improvement, (Bedford, UK: IFS Publications, 1989), p. 99.

construction activity processes due to the reduction in common cause variation (administrative support constraints) can be tracked through process control charts, as shown in Figure 5-2. More often than not, root-causes of common cause problems can be linked to the management of the construction inputs at the beginning of the on-site construction activity process (see Figure 1-3). Removal of common causes due to the system is the responsibility of management. Again, the Lost Time Pareto Charts shown in Chapter Two can effectively focus management's attention to the "vital few" factors that present the greatest potential for improvement. Other traditional methods of gathering and analyzing data; such as, Formen Delay Surveys and work sampling[9] also may be used to fine causes of constraint problems. Although these techniques may provide faster data, the accuracy of Lost Time Data is difficult exceed.

A task team should be commissioned to develop and implement improvements to each project administrative support process that the project team identifies as a priority area for improvement. The individual worker can do nothing about common causes due to administrative support processes; however, he can often contribute to

[9]Oglesby, pp. 156-180.

improvements in the way his work is done through suggestions. As such, task team membership must cut across organizational lines both horizontally and vertically.

Incremental improvements that improve a project's system and procedures of administrative support will result in less lost time, fewer errors and constraints, and increased productivity. These solutions should be tested and standardized on a project-wide basis. Upon verification of the successful standardization of the solution on a project-wide basis, the project team and company's Executive Steering Committee should determined if the improvement can be applied on a company-wide basis. Solutions that have company-wide applicability should then be tested and standardized as company procedures.

5.2.3. INNOVATIVE METHODS IMPROVEMENT

Innovation involves a drastic improvement in the status quo as a result of a large investment in new technology and/or equipment[10]. As shown in Figure 5-1, top and middle management must assume leadership in bringing about an innovative breakthrough. Construction industry top management must establish clear-cut goals

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[10]Imai, p. 6.

and guidelines for research and development that deals with the issues that will enable the industry to better serve consumer groups and provide a competitive edge. Presently, support for research and development in the United States' construction industry is minimal in contrast to the amount of support that Japanese engineering and construction firms dedicate to in-house research efforts[11]. The potential effect of innovation on construction activity processes is shown in Figure 5-3.

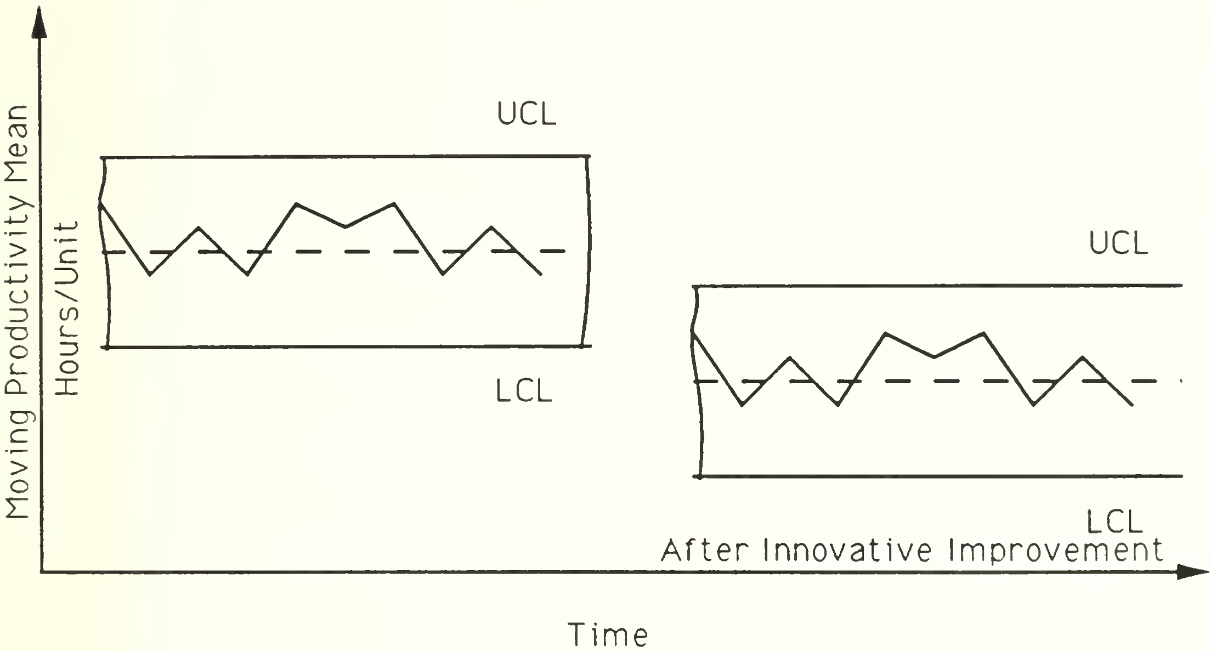

Figure 5-3 Effect of Innovation on Productivity

11"Quality Management Organizations and techniques", Consturction Industry Institute, Source Document 51, (Aug 1989), pp. 64-68.

6. CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSIONS

Total Quality Management methods can enable the construction industry to better meet Owner's needs through continually improvements in performance. TQM methods provide both the humanistic philosophies and technical procedures required to achieve continuous performance improvement. The essential first steps toward performance improvement is top management's commitment and communication of the need for improvement, and management's understanding that the majority of problems within an organization are due to the system in which work is done. TQM is not a program. Rather, TQM is a cultural change that encourages everyone in the organization to work together to identify and permanently remove system problems; thereby, improve quality, decrease waste, errors and cost, and improve the productivity of each process.

By placing emphasis on better customer satisfaction at each step in the construction process, the parties involved in construction can continually improve the methods and procedures for construction. On-site construction activities are distinct processes with

defined procedures for the management of construction inputs, and with defined construction methods for transforming the inputs into a facility that meets contract requirements. The Deming/Shewhart Plan-Do-Check-Act Cycle provides a systematic method for achieving and sustaining process improvements.

The essential first step in the PDCA Cycle is the measurement and analysis of process performance data as a basis for identifying areas for improvement. Project Lost Time and Crew True Unit Rate data enables the project team and task teams to identify the causes of problems impacting the construction process.

Separating lost-time hours from work-time hours, allows top management and field supervisors to pinpoint and address problems in both the system of administrative support procedures and construction methods. Management's acceptance of responsibility for lost time, and the field supervisor's acceptance of responsibility for crew true unit rates allows the project organization to focus attention on improvements based on firm data. Implementation of the PDCA cycle using Lost Time and True Unit Rate data provides an effective method of method for discovering causes of problems and implementing solutions at all levels within the construction organization.

6.2. RECOMMENDATIONS

Based on findings from this literature review, the following recommendations are offered for consideration by the construction industry:

1. Significant performance improvement can be achieved by focusing attention on the process of construction with the aim of better meeting the customer's needs.
2. TQM requires the support of all parties involved in the construction process.
3. The TQM approach must meet the specific needs of the company.
4. Training at each level within the organization is essential to the success of improvement efforts. Training efforts should address both the humanistic and technical aspects of TQM. A TQM consultant with at least a master's degree in statistics should conduct training on statistical process control techniques.
5. TQM implementation efforts should begin on a pilot scale, and successes should be publicized to gain full acceptance and understanding of the potential benefits of a TQM approach.

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VITA

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